Technology Barriers for 4G Basestation Transmitters

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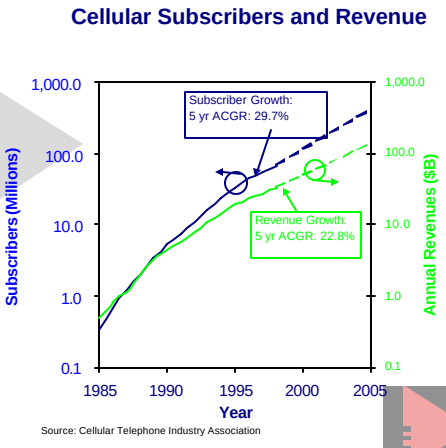
Business Constraints in the Cellular/PCS Industry

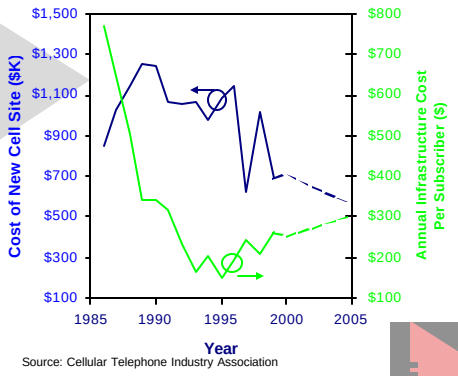
- Voice still dominant application, but data is picking up
  - ⇒ *Increasing Capacity Requirements*
- Urban: Capacity log jam
  - ⇒ *Revenue growth slows*
- Rural: Coverage limited
  - ⇒ *Revenue growth slows*



Business Constraints in the Cellular/PCS Industry (cont.)

- Infrastructure Side Dilemma
  - ⇒ *Infrastructure must expand but incremental capital outlays must not increase*
- Subscriber Side Dilemma
  - ⇒ *Size, features, and quality of service must improve, but not at higher cost*

Cellular Infrastructure Cost Trends

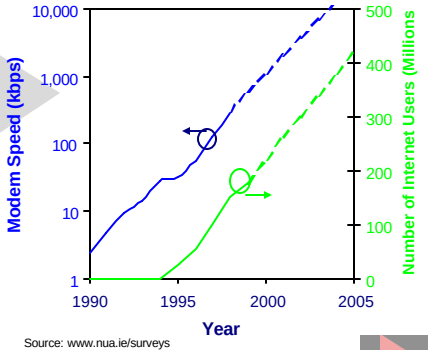


Source: Cellular Telephone Industry Association

Trends in Internet Access

- Large Growth in Internet Subscribers
  - – *Increased Points of Presence*
- Growth in Web-Based Applications
  - – *Data Rates Increasing*
- Growth in E-Commerce
  - – *Data Volume Increasing*
- Dilemma: Rapid Deployment of New Infrastructure Deployment Needed

Internet Growth



Source: www.nua.ie/surveys

Mobile Phone Markets Today and Tomorrow

	2G Today	3G ~2001	4G ~2005
Access	Extensive Coverage – 100% major US highways – Domestic Roaming	Complete Coverage – All urban & suburban areas – International Roaming	Ubiquitous Coverage – Indoor and Outdoor – World Wide Roaming
Bandwidth	Low Data Rates – 9.6 kbps to 128 kbps	Higher Data Rates – 384 kbps to 2.4 Mbps	Ethernet rates – to 10 Mbps
QoS	Reliability ~95%	Reliability > 99.9%	Reliability > 99.99%
Cost of Service	Inexpensive in developed countries	Affordable in developing countries	Affordable worldwide
Competition	Mobile Radio	Satellite Mobile Phone	Land Lines and Broadband Wireless

Infrastructure Technology Pressures

Driver	Pressure Level
Service Access	Medium
Information Bandwidth	High
Quality of Service	High
Cost of Service	Low

Activity Focus

Strategies for Relieving 4G Technology Barriers

Industry ☛

University ☛

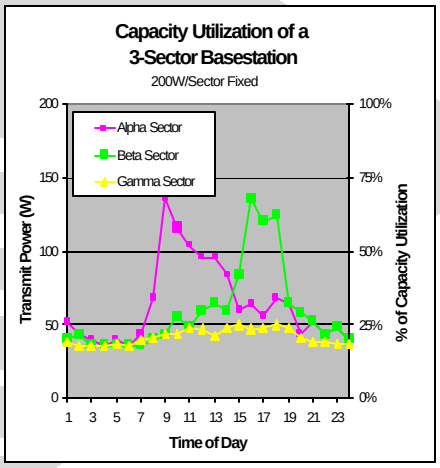
- Get Better
  - Incremental Improvements in Existing Technology
  - Safer
- Get Smarter
  - Revolutionary Solutions to Old Problems with New Technology
  - More Risky

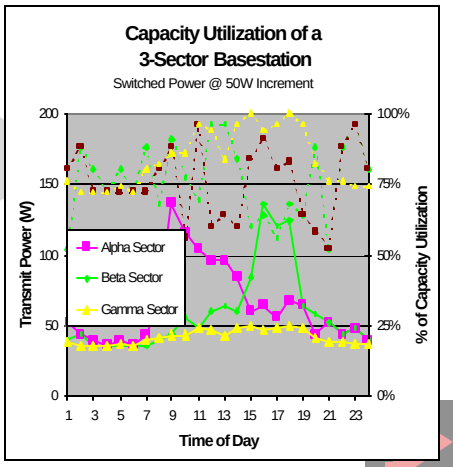
Base Station Technology: Getting Smarter

- Smart Antennas
- Smart Amplifiers
- Smart Devices

Smart Antennas

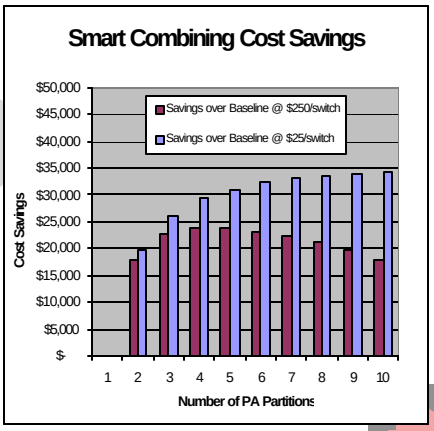
- Allow Higher Utilization of Basestation Capacity





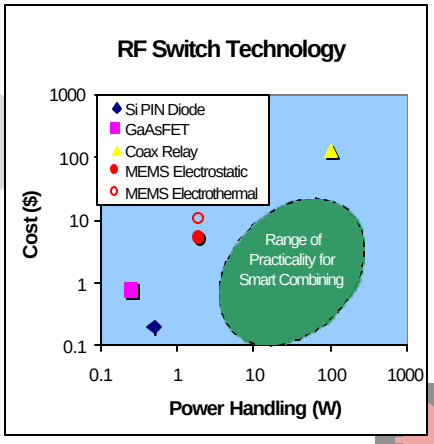
Beam Forming Requires High Power Switching

- Architecture Paradigm will Shift
  - *From:* Single Large PA
  - *To:* Small Partitioned PA's
- RF Switch Technology is Key
  - High Power Handling
  - Fast Switching
  - Low Loss
  - Low Cost

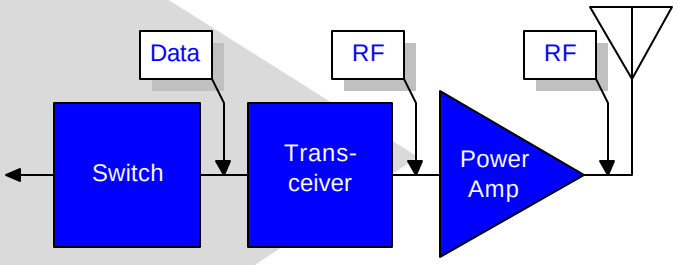


RF Switch Options for Active Combiners

- Conventional Technology:
  - Too Lossy
    or
  - Too Costly
    or
  - Not Enough Isolation
- MEMS
  - Good Trade-off
  - Cost?
    - Packaging is Key
  - Reliability?

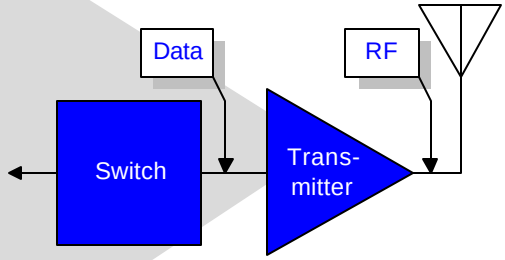


Conventional Transmitter



- RF Signal Created by Tranceiver
- RF Signal Amplified (and Distorted) by Power Amplifier

Smart Transmitter



- I-Q Stream used to Correct PA Distortion With Transmitter

Transmitter Linearity Depends on Device Technology

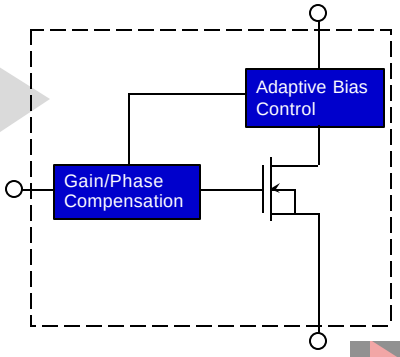
- CDMA Capacity is Dominated by Forward Link E_c / I_0
- Basic Technology not Linear Enough
- Correction Techniques Can Improve 10 to 30 dB, but at a Significant Cost Impact

Transistor Technology	Gain[2]	Class-AB IMD	Power Output[2]	Cost[2]
Bipolar	8 dB	-30 dBc	150 W	$0.45/W
LDMOS	10 dB	-35 dBc	90 W	$0.65/W
GaAsFET	14 dB	-35 dBc	60 W	$1.25/W

[1] Single-ended [2] At 1 GHz

Smart RF Power Devices

- Technology: Standard GaAs and Silicon - Mature
- On-chip Pre-D, adaptive bias control
- Packaging Technology / Economics Dictated by Power Device
- Goal: Three Terminal Device with 10-15 dB Improvement in IMD Performance



Conclusions

- Industry - Getting Better
- University - Getting Smarter
- Collaboration - Doing It Faster